THE DELAWARE LIMESTONE[1]

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CONTENTS

HISTORICAL REVIEW

The division and correlation of the Devonian limestones of Ohio have been a subject of consideration by geologists for many years, and there have been decided differences of opinion. Recently Dr. Charles K. Swartz, of Johns Hopkins University, and the writer have studied these limestones, in the main working independently, but arriving at quite similar general conclusions. The following rather brief chronological review of the most important opinions will probably acquaint the reader with an outline of the subject under consideration.

In 1838 Professor Locke adopted the name "Cliff limestone" "for the very extensive deposit of limestone above the blue limestone"[2] (the latter limestone he described as alternating with layers of marl in southwestern Ohio, and it belongs in what is now known as the Cincinnatian series). In 1842 Dr. A. Clapp, in describing the rocks at the Falls of the Ohio and vicinity, stated that "under the name Cliff limestone is here included all the group above the blue limestone and marls of Cincinnati, to the black slate."[3] The

[1] Published by permission of Edward Orton, Jr., state geologist of Ohio.

[2] *Second Annual Report of the Geological Survey of Ohio*, p. 211.

[3] *Proceedings of the Academy of Natural Science*, Philadelphia, Vol. I, p. 178.

black slate mentioned by Dr. Clapp is now known as the New Albany black shale, which in a general sense may be regarded as the western continuation of the Ohio shale. It was, furthermore, reported that Dr. Clapp made the following correlations between divisions of the Cliff limestone and certain New York formations:

> The lower and middle portions of the Cliff limestone he conjectures to be equivalents of the Niagara limestone and Gypseous shales; the entire mass called the Cliff limestone represents therefore the Niagara limestone, Gypseous shales, water-lime, Onondaga limestone, etc., to the Marcellus shales.

It is stated by Dr. Newberry that the Corniferous limestone was first identified in Ohio by Professor Hall in 1841;[1] but in his paper entitled "Notes upon the Geology of the Western States," Professor Hall's statement is simply this: "In examining the upper part of the 'cliff limestone' I found it, so far as lithological characters are concerned, a continuation of the Helderberg group;" and the Niagara limestone is mentioned as occurring in "the vicinity of Columbus."[2] In another article, however, published the following year, Professor Hall reported the occurrence of the Corniferous limestone in the vicinity of Columbus, stating that

> a short distance to the west of that place [Columbus] the Corniferous limestone of New York appears, presenting its characteristic fossils. This mass is the upper part of the cliff limestone formation of Dr. Locke, the name by which it is generally known in Ohio.[3]

In 1847 de Verneuil stated that the Devonian system in New York

> is principally composed of schists and argillaceous sandstones, which, as we have said, are lost and disappear in the West; it thence results that in the states of Ohio, Indiana, and Kentucky it is reduced to the black schists, which represent the Genesee slate, and to a calcareous band which represents at once the Corniferous and Onondaga limestones and the Hamilton group of the state of New York.[4]

Under Dr. Newberry's direction, the Devonian limestones, which he called the Corniferous, were carefuly studied during the progress

[1] *Report of the Geological Survey of Ohio*, Vol. I, Part I (1873), p. 142.

[2] *American Journal of Science and Arts*, Vol. XLII (1842), p. 58.

[3] *Transactions of the Association of American Geologists and Naturalists* (1843), p. 273.

[4] Hall's translation in *American Journal of Science and Arts*, second series, Vol. V (1848), pp. 369, 370. The original is in the *Bulletin de la Société géologique de France*, second series, Vol. IV (1847), p. 680.

of the Second Geological Survey of Ohio, and in his first report their distribution was shown on the "Preliminary Geological Map of Ohio,"[1] together with some account of their occurrence, lithology, and fossils;[2] while the chapter on the Devonian system in the first volume of the Geological Survey of Ohio contained a more elaborate description.[3] He made two divisions of this limestone: the upper one, termed the *Sandusky limestone*, described as blue and thin-bedded, from fifteen to twenty feet thick, quarried at Sandusky and Delaware; and the lower division, called the *Columbus limestone*, well shown in the quarries near that city, and described as a very light-colored limestone often containing chert.[4] Dr. Newberry stated that the upper portion of the Sandusky limestone contained several characteristic Hamilton fossils in considerable abundance, as *Spirifer mucronatus*, *Cyrtia* [*Cyrtina*] *hamiltonensis*, etc.; and on account of the presence of these fossils he was for a long time in doubt whether the Sandusky limestone should not be considered as a representative of the Hamilton rather than of the Corniferous group; but, on gathering all the fossils of this formation, the list was found to include a much larger number of Corniferous than of Hamilton species.[5]

Dr. Newberry concluded that the limestones were to be correlated with the Corniferous of New York, while the Hamilton was restricted to a bed of marl and marly limestone which at Prout's Station, south of Sandusky, was stated to be from ten to twenty feet in thickness, containing "great numbers of Hamilton fossils, with none which are peculiar to the Corniferous." At Delaware, in central Ohio, a light-gray marl between the Black shale and Corniferous limestone was thought to probably represent the Hamilton, but it was stated that south of this locality no trace of it had yet been found.[6]

On the contrary, Professor N. H. Winchell, who described several of the counties in central and northwestern Ohio, came to the conclusion that the upper Corniferous was probably to be correlated with the Hamilton formation. Under his description of Delaware County we find the following:

[1] Geological Survey of Ohio, *Report of Progress in 1869* (1870), frontispiece.

[2] *Ibid.*, pp. 17, 18.

[3] *Report of the Geological Survey of Ohio*, Vol. I, Part I (1873), pp. 142–49.

[4] *Ibid.*, p. 143. [5] *Ibid.*, p 144. [6] *Ibid.*, p. 150.

The lithological characters of the Michigan Hamilton are the same as those of the upper Corniferous in Ohio, and it is hardly susceptible of doubt that they are stratigraphically identical.[1]

In his sections Professor Winchell used the names "Tully limestone," and "Hamilton," followed in the descriptive part by an interrogation point, and "Corniferous limestone."[2] The upper limestone is also mentioned under the name of "Delaware stone"[3] and "Delaware limestone,"[4] but apparently without the intention of considering it as a formation name. Later, however, in describing Paulding County, in the northwestern part of the state, Professor Winchell stated that close "attention was paid to the solution of the question, 'Do Hamilton fossils extend through the whole of the blue limestones?'"[5] and the conclusion was "that the beds that hold these Hamilton fossils are very near the bottom of the blue limestone."[6] Professor Winchell accepted this as sufficient proof of the correctness of his correlation with the New York formations, consequently on his "General Section of the Rocks of Paulding and Defiance Counties" appear the names "Tully limestone" and "Hamilton limestone of New York," below which are given the "Corniferous and Onondaga limestones of New York."[7] In the legend of the geological maps of Delaware, Paulding, and Defiance Counties, all by Professor Winchell, appears the name "Hamilton group,"[8] which is given a distinct area on the maps.

This correlation was opposed by Dr. Newberry, who said:

The Tully limestone? of Professor Winchell's sections is certainly Hamilton, as I have obtained from it *Tropidoleptus carinatus*, *Pterinea flabella*, *Nyassa arguta*, *Spirifera mucronata*, etc.

And regarding the Hamilton limestone of Professor Winchell he wrote as follows:

I think it will be seen that the weight of evidence is decidedly in favor of its being of Corniferous age. The cherty layers which lie between the Huron shale and the quarry-stone at Delaware are probably Hamilton, but the quarry-stone

[1] *Ibid.*, Vol. II, Part I (1874), p. 289.

[2] For example, see the section "through the Olentangy Shale and Hamilton Limestone, Five and a Half Miles below Stratford," on pp. 293, 294.

[3] *Ibid.*, pp. 293, 302. [4] *Ibid.*, p. 294. [5] *Ibid.*, pp. 341, 342.

[6] *Ibid.*, p. 343. The statements just quoted also appeared on pp. 395, 397, of the excerpt from the report on Paulding County, entitled "On the Hamilton in Ohio," published in the *American Journal of Science*, third series (1874), Vol. VII.

[7] *Ibid.*, p. 342. [8] *Ibid.*, facing pp. 272, 336, and p. 422.

itself, though containing some fossils which are common to the Hamilton and the Corniferous, has never yielded me any exclusively Hamilton fossils.[1]

In 1875 Professor Winchell read a paper "On the Parallelism of Devonian Outcrops in Michigan and Ohio" before the American Association, in which he gave a table of parallel "Devonian Outcrops in Michigan and Ohio," in which Sandusky, Delaware, Marion, and sec. 17, Defiance, Defiance County, Ohio, are correlated with the Hamilton blue limestone as exposed in the vicinity of Thunder Bay, Lake Huron, and near Charlevoix, Lake Michigan, in the northern part of the Lower Peninsula.[2]

Dr. Newberry's objection was restated in the succeeding state report under the "Review of the Geological Structure of Ohio," where he expressed this opinion:

> In regard to the position of the Sandusky limestone, it must be said that the weight of evidence is in favor of retaining it in the Corniferous. . . . . There is even in New York much in common between the fossils of the two groups, and all the fossils which Professor Winchell relies upon as criteria for distinguishing the Hamilton from the Corniferous, are found in both; hence their presence in the Sandusky limestone is no proof of its Hamilton age. It should also be said that quite a number of fossils are found in the Sandusky limestone which are regarded as characteristic of the Corniferous.[3]

This volume contains Dr. Orton's report on the geology of Franklin County, in central Ohio, in which he followed Dr. Newberry in correlating all of the Devonian limestone with the Corniferous. The upper division, however, of thirty-two feet of blue limestone he states is, "from its occurrence at Delaware, and the extensive use made of it at that point, well named the *Delaware limestone;*"[4] and this name was used in place of Newberry's older one of "Sandusky limestone." For the lower division Dr. Orton retained the name "Columbus limestone," and described a six-inch stratum named the "bone-bed" containing large numbers of the teeth, plates, and

[1] *Ibid.*, footnote, p. 290. For similar statements see Dr. Newberry's criticism of Professor Winchell's geological classification of Paulding County (footnote, pp. 337, 338); and Dr. Newberry's description of the Corniferous limestone of Erie County (pp. 191, 192).

[2] *Proceedings of the American Association for the Advancement of Science*, Vol. XXIV (1876), Part II, p. 59.

[3] *Loc. cit.*, Vol. III, Part I (1878), p. 11.

[4] *Ibid.*, p. 606.

bones of fishes, which occurs at the top of the Columbus and separates it from the Delaware limestone.[1]

In discussing the correlation used by Professor Winchell in his report on Delaware County, Dr. Orton said:

> The Columbus and Delaware limestones probably cover the age in which the Corniferous limestone, and the Hamilton group, in part, of New York were forming; but there seems no warrant whatever for identifying the subdivisions of our scale with the subdivisions recognized five hundred or a thousand miles away.[2]

In 1877 Professor Hall visited the Falls of the Ohio, near Louisville, and correlated the hydraulic and encrinal limestones, which are the higher limestones of the section, with the Hamilton group of New York, and said that "in the state of Ohio similar conditions may be inferred, from the fact that certain species of known Hamilton fossils are published in the Ohio Geological Reports as from the Corniferous group."[3]

In 1878 Professor Whitfield visited Franklin County, and on the banks of the Scioto River, six miles northwest of Columbus, made the most important discovery relating to the classification of the Devonian limestones that had been made in central Ohio. In a bed of dark-brown, bituminous shale, in the lower part of the Delaware limestone, flattened specimens of *Liorhynchus limitaris* (Van.), *Discina minuta* Hall, and *Lingula manni* Hall were found, the two former being strictly characteristic species of the Marcellus shale of New York. On the following day the same shale was found farther north, nearly opposite Dublin, containing *Liorhynchus limitaris* (Van.) and *Discina lodensis* (Van.). This shale was reported only a few feet above the "bone-bed," and Professor Whitfield stated: "I have no hesitation in pronouncing [it] the equivalent of the MARCELLUS SHALE of New York."[4] This discovery seemed to confirm Professor Winchell's opinion that the Delaware limestone of Delaware County represented the Hamilton formation of New York.

[1] See *Ibid.*, pp. 605, 606, 610. [2] *Ibid.*, p. 634.

[3] *Transactions of the Albany Institute*, Vol. IX (1879), p. 179. The same statement was published in *Palæontology of New York*, Vol. V, Part II, text (1879), pp. 146, 147.

[4] *Proceedings of the American Association for the Advancement of Science*, Vol. XXVIII (1880), pp. 297, 298.

Professor Whitfield published later a list of the fossils found in these shales, together with a description of two new species, under the title of "Species from the Marcellus Shales."[1] A more complete account of their stratigraphy was also published under the title of "Note on the Marcellus Shale and Other Members of the Hamilton Group in Ohio, as Determined from Palæontological Evidence."[2] In this article Professor Whitfield positively identified the shales as of Marcellus age, stating that

> only a few feet above the "bone-bed" occurs the dark-brown shale in question, with the peculiar fossils, which I have no hesitation in pronouncing the equivalent of the Marcellus shales of New York. Admitting this—and there certainly appears to be no alternative—the rocks found above this limit should represent the Hamilton group of the New York system.[3]

In the Ohio report Professor Whitfield stated that in August, 1879, he

> read a notice of the occurrence in Ohio of rocks representing the Marcellus shales of New York . . . . in which it was shown that a considerable thickness of the limestones previously recognized as "Corniferous" in Ohio, were above the horizon of the beds which I had recognized, from palæontological and lithological evidence, as of the age of the Marcellus shale, and would be of necessity equivalents of the Hamilton group.[4]

Finally, Professor Whitfield published descriptions of several "species from the limestones above the 'bone-bed,' in the vicinity of Columbus, Ohio, and not known to occur below that horizon," which included such well-known Hamilton species as *Spirifer ziczac* Hall, *Pterinea flabella* (Con.) Hall, *Nyassa arguta* H. & W., and *Grammysia bisulcata* (Con.) H. & W.[5]

Dr. Orton, in describing the geological scale of Ohio in the volume on petroleum and natural gas, changed the name of the formation from the "Corniferous" to the "Upper Helderberg limestone," and assigned the following reason:

[1] *Annals of the New York Academy of Sciences*, Vol. II (1883), pp. 212–15. Descriptions of all the species were published in the *Report of the Geological Survey of Ohio*, Vol. VII (1893 [1895]), pp. 441–47.

[2] *Annals of the New York Academy of Sciences*, Vol. II (1883), pp. 233–41. This article, with additions, was republished in *Report of the Geological Survey of Ohio*, Vol. VII, pp. 432–41.

[3] *Ibid.*, p. 235, and *Report of the Geological Survey of Ohio*, Vol. VII, p. 433.

[4] *Report of the Geological Survey of Ohio*, Vol. VII, p. 434, footnote.

[5] *Ibid.*, pp. 447–52.

All of the limestone of the Devonian age in Ohio has been referred by Newberry, to the Corniferous limestone, and this term is in general use at the present time. It may be questioned whether it is wise to break in upon this here, but inasmuch as several geologists hold that the Devonian limestone of Ohio covers more than the single epoch known as Corniferous in New York, a more comprehensive term, viz., the Upper Helderberg limestone, is counted preferable. A twofold division of the series is possible and proper in Ohio, the division being based on both lithology and fossils. The divisions are known as Lower and Upper Corniferous, or as Columbus and Delaware limestones. For the upper division the term Sandusky limestone is sometimes used.[1]

On the "Geological Map of Ohio," accompanying this report, the "key to formations" mentions the Upper Helderberg limestone, Marcellus shale, Hamilton limestone, and Hamilton shale, which are all represented by one color on the map.

The substitution of the name "Upper Helderberg limestone" for "Corniferous limestone" did not meet any of the objections raised by Winchell, Hall, and Whitfield to the Newberry classification of the Devonian limestones of Ohio, because, so far as the later formations are concerned, it is not a more comprehensive term than the "Corniferous limestone," and in its classic locality, the Helderbergs of eastern New York, has never been applied to rocks above the base of the Marcellus shale. The name "Helderberg division" was proposed by Vanuxem in 1842, and included all the formations occurring between the top of the Niagara limestone and the base of the Marcellus shale.[2] In the following year Mather's report appeared, in which the rocks of the Helderberg mountains are described, and it is stated that, on account of their excellent development at this locality, "forming a natural group, strongly marked in their lithological and paleontological characters from the strata lying above and below them, the term of *Helderberg division* is used to designate them."[3] In the northern Helderbergs nearly all of the subjacent Ontario division is absent, and Mather's Helderberg division included all the formations found at this locality between the top of the Hudson

[1] *Ibid.*, Vol. VI (1888), pp. 20, 21. "Upper Helderberg limestone" is also used by Dr. Orton for the formation in his article on "The Trenton Limestone as a Source of Petroleum and Inflammable Gas in Ohio and Indiana" (*Eighth Annual Report of the United States Geological Survey*, Part II (1889), p. 568.)

[2] *Geology of New York*, Part III (1842), pp. 13, 15, 16.

[3] *Ibid.*, Part I (1843), p. 325.

(Lorraine beds) and the base of the Marcellus shale. Later studies, however, have shown that the "Pyritous slates," forming the basal member of his Helderberg division, are probably of Salina age;[1] while Mather's succeeding division—the Water limestone—which he gave as composed of two members, the Water limestone and Tentaculite limestone, now called the Rondout waterlime and the Manlius limestone, is also separated from the Helderbergian series as defined by Dr. John M. Clarke, and put in the subjacent Cayugan series.[2]

Professor Hall in 1859 divided the rocks of the Helderberg mountains into the Lower and Upper Helderberg groups, which were separated by the Oriskany sandstone and Cauda-galli grit.[3] The Upper Helderberg group was composed of the Schoharie grit and Onondaga and Corniferous limestones; or, in other words, it included the rocks between the top of the Cauda-galli grit (now called Esopus grit) and the base of the Marcellus shale.

Regarding Whitfield's discovery Dr. Orton said:

> At a few points in central Ohio the upper division [Delaware limestone] has been found in a shaly state and carrying characteristic fossils of the Marcellus slate. This fact was first noticed in its true significance by Whitfield.[4]

The name "Upper Helderberg limestone" was used by Dr. Orton for the formation, and the same reasons for its use were published in his first annual and final report of the Geological Survey of Ohio;[5] but in his last review of the "Geological Column of Ohio" he returned to the earlier name of "Corniferous limestone."[6]

In the last edition of Dana's *Manual* the Delaware limestone is apparently considered as of Hamilton age, for in giving the distribution of its beds it is stated that "they appear also in Ohio, as

[1] Hartnagel, New York State Museum, *Bulletin No. 69* ("Report of the State Paleontologist," 1902), 1903, pp. 1116, 1170, 1171.

[2] New York State Museum, *Handbook No. 19* (1903), pp. 8, 9, 14.

[3] *Palæontology of New York*, Vol. III, Part I (1859), p. 97.

[4] *Report of the Geological Survey of Ohio*, Vol. VI (1888), p. 22.

[5] *First Annual Report of the Geological Survey of Ohio* (1890), pp. 24–26; *Report of the Geological Survey of Ohio*, Vol. VII (1893 [1895]), pp. 18, 19.

[6] *Nineteenth Annual Report of the United States Geological Survey*, Part IV (1899), pp. 638, 646, 682.

twenty-five feet of impure bluish limestone,"[1] although under the account of the Corniferous limestone the Delaware is mentioned as the upper division in Ohio.[2]

In 1898 Professor John A. Bownocker published a paper on "The Paleontology and Stratigraphy of the Corniferous Rocks of Ohio," in which is given a number of sections of the limestone as shown in various quarries, accompanied by lists of fossils collected at twelve different localities in the state. The Corniferous limestone of this article includes both the Columbus and Delaware divisions, and at the close of the discussion on the "Relation of the Fauna above the Bone-Bed to that Below" it is stated:

> It appears, therefore, that the difference between the faunas above and below the bone-bed in the central Ohio area is not great, that this difference is most conspicuous at Delaware and diminishes to the north, being least at Sandusky.[3]

Dr. Edward M. Kindle carefully studied the Devonian limestone of southern Indiana and northern Kentucky, and stated that near the Ohio River it "is readily separated into two divisions, which are easily distinguished from each other both by lithological and paleontological characters."[4] The lower division he named the "Jeffersonville limestone" and the upper one the "Sellersburg beds." Kindle's *Bulletin* was based on a thorough study of the fossils, and in discussing the "Correlation of Faunas" he stated:

> The Corniferous fauna of New York suffers no very important modifications in its western extension. The large number of species common to the faunas of the Corniferous limestone of New York and the Jeffersonville limestone, especially among the corals, leaves no doubt as to the equivalence of the two faunas. . . . . In southern Indiana we find in the Sellersburg beds a fauna containing many of the most characteristic species of the Hamilton of New York. . . . . This fauna is not mingled with the Corniferous, as was once supposed, but occurs above that fauna in the Sellersburg beds. The presence in it of such characteristic Hamilton fossils as those mentioned seems to leave no doubt of its equivalence to the New York Hamilton.[5]

It will be noticed that this conclusion regarding the correlation of these limestones is in perfect harmony with the later views of Professor Hall.

[1] *Manual of Geology*, 4th ed. (1895), p. 592. [2] *Ibid.*, p. 581.

[3] *Bulletin of the Scientific Laboratories of Denison University*, Vol. XI, p. 39.

[4] *Bulletin of American Paleontology*, No. 12 (1899), p. 8. [5] *Ibid.*, p. 110.

A further elaboration of this work by Dr. Kindle was later published in an Indiana *Report* which contained an account of the Devonian stratigraphy of Indiana, together with descriptions and figures of its fossils. Dr. Kindle's conclusions regarding the correlation of Devonian limestones of Indiana are stated as follows in this report:

> The problem of the correlation of the Devonian limestones with the New York scale is much more difficult for some parts of the Indiana province than for others. In the vicinity of the Falls of the Ohio we find two quite distinct and well-marked faunas. These are the *Spirifer granulosus* and the *Spirifer acuminatus* faunas, and represent respectively the Hamilton and Corniferous faunas of New York. Near the Falls of the Ohio, the Sellersburg beds, and the Jeffersonville limestone, which carry these faunas, are sharply differentiated lithologically, the Jeffersonville limestone being a nearly pure limestone, and representing clear water conditions during its deposition, while the Sellersburg beds are composed of an impure argillaceous limestone. In the northern part of the southern Indiana area these two formations cease to be sharply differentiated lithologically, and merge into each other in a limestone which is neither so pure as the Jeffersonville limestone nor so argillaceous as the Sellersburg beds near the Falls. Associated with the loss of individuality of these two formations occurs a mingling of their two faunas which renders them indistinguishable as separate faunas.
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> In the Wabash area the faunas of the Devonian limestone are even more distinct than that at the Falls of the Ohio. In the lower one *Spirifer acuminatus* is an abundant fossil, and the fauna does not differ greatly from that in the Jeffersonville limestone at the Falls of the Ohio. The upper fauna is a distinctly Hamilton fauna, but entirely different from the Hamilton fauna of southern Indiana.[1]

At an early date Hamilton fossils were identified by Professor Alexander Winchell from the northern part of the Lower Peninsula of Michigan and the rocks referred to the Hamilton group. In 1870 he named it the "Little Traverse group,"[2] which in 1895 was shortened by Dr. Lane to the "Traverse group."[3] The southern part of the state is so heavily mantled by drift that formerly it was not known whether the formation occurred there or not; but later study of well sections has shown its presence with a thickness of about eighty feet. On a recent geological map of the Lower Peninsula the formation is shown crossing Monroe and Lenawee Counties

[1] *Twenty-fifth Annual Report of the Department of Geology and Natural Resources of Indiana* (1900), p. 570.

[2] *Report of Progress*, State Geological Survey of Michigan, p. 28.

[3] *Geological Survey of Michigan*, Vol. V, Part II, p. 24.

in the southeastern corner of the peninsula,[1] and entering Ohio at about the locality where the Hamilton or upper part of the Corniferous has been represented on the state maps. Since then Professor Sherzer has given a more detailed account of the "Traverse (Hamilton) group" of Monroe County, Mich., in his geological report of that county.[2]

In 1902 Professor Weller published a paper on "The Composition, Origin, and Relationships of the Corniferous Fauna in the Appalachian Province of North America," in which he stated that "in Ohio the fauna occurs in the Columbus limestone."[3] The Delaware limestone was not mentioned, and apparently he did not consider its fauna as that of the Corniferous. Professor Claypole, in his account of "The Devonian Era in the Ohio Basin," stated near the close of the section devoted to "The Corniferous Limestone," that

> what has already been said must not be referred to the whole mass of strata which have usually been classed under the name Corniferous in Ohio geology, but only to that part lying below the bone-bed and to the bone-bed itself.[4]

The division succeeding the bone-bed Professor Claypole called "the Corniferous-Hamilton period," and stated that "the period was, in Ohio, evidently one of transition."[5] His correlation of the several members of the two periods is shown in the following table:

Shale at Prout's Station - - - -	Hamilton
Blue limestone, thin-bedded -	Corniferous-Hamilton
Dublin blue [brown] shale - - -	Marcellus
Bone-bed - - - - - -	Corniferous
Gray and buff limestones - - -	Corniferous[6]

The same year Professor Schuchert, in his paper on "The Faunal Provinces of the American Middle Devonic," apparently accepted Whitfield's correlation of the Devonian limestones of central Ohio.[7]

Finally, in New York state, which is the standard one for the correlation of the American Devonian, the geographic name of "Onondaga limestone" has been adopted in place of "Corniferous

[1] *Water-Supply and Irrigation Papers*, U. S. Geological Survey, No. 30 (1899), Plate VI.

[2] *Geological Survey of Michigan*, Vol. VII, Part I (1900), pp. 31–35.

[3] *Journal of Geology*, Vol. X, p. 424.

[4] *American Geologist*, Vol. XXXII (1903), p. 31.

[5] *Ibid.*, p. 35. [6] *Ibid.*, p. 35. [7] *Ibid.*, p. 148.

limestone," which was based upon a lithologic character of the formation.[1]

DESCRIPTION OF THE DELAWARE LIMESTONE

The principal object of this paper is to consider the upper formation of the Ohio Devonian limestones, and decide upon the name which shall be applied to it. The name "Delaware limestone" was first definitely applied to this division as a formation name by Dr. Orton, and published in 1878. He briefly described it as "the blue limestone, thirty-two feet in thickness, which is, from its occurrence at Delaware, and the extensive use made of it at that point, well named the *Delaware limestone.*"[2] So far as the writer is aware, the term "Delaware limestone," when published by Dr. Orton in 1878, was available for the name of a geological formation, and was definitely described in Franklin County, so that there is no doubt regarding its limits. Since 1878 the name "Delaware," forming all or part of the designation, has been applied to at least three other geological divisions; but these names, if considered identical, will not replace Dr. Orton's "Delaware limestone," but will be abandoned because of preoccupation. The names are as follows: (1) *Delaware river beds*, applied by Dr. I. C. White to an upper Devonian terrane of northeastern Pennsylvania;[3] (2) the identical term, so far as the geographical part of the name is concerned—*Delaware stage*—was given by Professor Calvin to the lower part of the Niagaran series in eastern Iowa;[4] and (3) the name "Delaware mountain formation" has very recently been given by Mr. George B. Richardson to a Permian formation of southwestern Texas.[5]

Although Dr. Orton's name for this formation apparently referred to the exposures in the vicinity of Delaware, still the section giving its entire thickness which he described, and which may therefore be considered his type section, is in the Scioto valley, about one

[1] Clarke and Schuchert, *Science*, N. S., Vol. X (1899), p. 876; Clarke, N. Y. State Museum, *Handbook No. 19* (1903), pp. 8, 21, 22.

[2] *Report of the Geological Survey of Ohio*, Vol. III, Part I, p. 606.

[3] *Second Geological Survey of Pennsylvania; G*[6] (1882), p. 99.

[4] *Iowa Geological Survey*, Vol. V (1896), pp. 49, 50.

[5] University of Texas Mineralogical Survey, *Bulletin No. 9* (November, 1904), p. 38.

mile north of Dublin, in the northern part of Franklin County.[1] This region may, therefore, be considered as typical as that in the vicinity of Delaware, and has the advantage of showing clearly in several sections both the upper and lower limits of the formation. It will be interesting, therefore, to describe somewhat carefully a section to the south and another one to the north of the one described by Dr. Orton.

Fig. 1.—Shale zone forming the lower part of the Delaware formation, as shown on Slate Run. Its top is indicated by the hammer.

SLATE RUN SECTION

In Perry Township, on the eastern side of the Scioto River, three and one-half miles north of Marble Cliff, is a locality known as Slate Run Hollow, on the farm of Mr. George Matthews. The run is one and one-half miles north of Fishinger's bridge, and about five and one-half miles in a direct line northwest of the Ohio State University, and in the lower part of the stream is the pond of the Columbus Fish-

[1] Dr. Orton named it the "section of Corniferous limestone near Corbin's mill Perry Township," Vol. III, p. 604.

ing Club. Formerly the upper part of the Columbus limestone was fairly well shown in the bluff of the Scioto River for some distance below this locality, while Slate Run affords a good section of the Delaware limestone and the overlying Olentangy shale. At this locality Whitfield first noticed the brownish shales containing a Marcellus fauna, although in the description it is not located more definitely than "six miles northwest of Columbus." A section was furnished by Dr. Orton, which was published in Whitfield's paper.[1]

No.		Thickness (Feet)	Total Thickness (Feet)
13.	*Ohio shale.*—On the northwest bank, immediately above the outcrop of Olentangy shale, is about 6 feet of the typical black, thin, arenaceous shale of this formation. The line of contact is sharp between these two shales. Farther up the stream, near the fence, the top of the Olentangy shale is near water-level, above which is about 11½ feet of the Ohio shale. A little farther up the run, and above the fence, are a number of concretions of various sizes imbedded in the Ohio shale.	11½±	107
12.	*Olentangy shale.*—Bluish or greenish to drab argillaceous shale, with the lithological appearance of typical exposures of Olentangy shale in Delaware County. One thin layer of brownish shale occurs at about the middle of the cliff, and two layers near its base. There are also thin layers of impure limestone, especially in the lower part of the formation, one of which, about 6 feet above its base, is 5½ inches in thickness. On Dr. Orton's section the Olentangy shale is given as 15 feet in thickness,[2] but this is obviously an underestimate.	22⅔	95½−
11.	Top of *Delaware limestone.*—A rather thin-bedded bluish-gray limestone, with occasional layers of chert, which extends to the top of the cascade. It may also be seen on the steep southeast bank farther down the stream, which is the best place for measuring its thickness.	13+	72¾

[1] *Proceedings of the American Association for the Advancement of Science,* Vol. XXVIII (1880), p. 298.

[2] *Ibid.*, p. 298.

No.		Thickness (Feet)	Total Thickness (Feet)
10.	Brownish-gray thin-bedded limestone, alternating with layers of chert, shown to best advantage on the southeast bank, a little above the contorted layer in the bed of the stream. This zone is conspicuous in the glens farther north, in the southern part of Delaware County.	$6\frac{3}{4}\pm$	$59\frac{3}{4}$
9.	Rather heavy-bedded grayish to brownish limestone.	$2\frac{1}{3}$	53
8.	Zone of contorted thin limestone and chert shown in the bed of the run and on its banks farther down the stream. This corresponds to the contorted stratum noted by Professor Winchell in sections of this limestone in the southern part of Delaware County.[1]	$2\frac{2}{3}$	$50\frac{2}{3}$
7.	At the base of the limestone, directly on top of the shale zone, is a thicker layer of chert, followed by layers of brownish limestone $2\frac{1}{2}$ inches or more in thickness. The measurements for this zone vary from 1 foot 6 inches to 2 feet.	$1\frac{1}{2}+$	48
6.	Brown, bituminous shales weathering to a light gray or ash color. The layers are even and thin, rather arenaceous in places, interrupted by several layers of chert, and contain a considerable number of fossils, especially in the lower part, although the number of species is small. The measurements of this zone vary from 5 feet 10 inches to 6 feet 6 inches, and it is well exposed on the southeastern bank of the run, where it has the general appearance of a bank of shale. It is shown in Fig. 1, the top of the zone being indicated by the hammer. This is the shale which Whitfield correlated with the Marcellus of New York, and it forms the base of the Delaware formation in this section, which has a thickness of $32\frac{1}{4}$ feet.	$6\pm$	$46\frac{1}{2}$
5.	*Columbus limestone.*—In the upper part of the top stratum are numerous fragments of the teeth, plates, and bones of fishes, the *bone-bed* which is well shown on the southeastern bank of the run a little above the fall. In the quarry wall, 5+ inches below its top, *Spirifer acuminatus* (Con.) Hall occurs, and 7 feet 3 inches lower is the "smooth layer," which is found from 9 feet 2 inches to 10 feet 5 inches below the top of the Columbus limestone in all of the sections in the Columbus region. In the upper Casparis quarry there are apparently two such layers, the upper one 9 feet 7 inches, and the lower one 10 feet 6 inches, below the top of the formation.	$7\frac{3}{4}+$	$40\frac{1}{2}-$

[1] *Geological Survey of Ohio*, Vol. II, Part I (1874), p. 289, No. 22.

No.		Thickness (Feet)	Total Thickness (Feet)
4.	From the "smooth layer" to the level of the Fishing Club pond, which is mainly rather dark gray, fairly massive limestone.	10⅓	32⅔
3.	Mostly covered from the level of the pond to the top of the cliff just below the highway bridge.	9⅓	22⅓
2.	Zone of light gray, very fossiliferous limestone, at the base of which are numerous specimens of *Spirifer gregarius* Clapp.	3⅔	13
1.	Rather dark gray, fairly massive limestone to the base of the exposure, which formerly was about 7 feet above the level of the Scioto River. Zones 1 to 5, inclusive, are all in the Columbus limestone.	9⅓	9⅓

In the brown shales of No. 6 of the above section the writer has collected the following species:

1. *Liorhynchus limitare* (Van.) Hall.
2. *Orbiculoidea lodiensis* (Van.) Hall and Clarke.
3. *Orbiculoidea minuta* (Hall) Beecher.
4. *Martinia maia* (Billings) Schuchert.
5. *Tentaculites scalariformis* Hall.
6. *Crinoid* stem (small one).

At this locality Whitfield found:

1. *Liorhynchus limitare* (Van.) Hall.
2. *Orbiculoidea minuta* (Hall) Beecher.
3. *Lingula manni* Hall.[1]

The range of the above species in New York is as follows: *Liorhynchus limitare* (Van.) Hall is, perhaps, the most characteristic species of the Marcellus shale; *Orbiculoidea lodiensis* (Van.) Hall occurs in the Hamilton beds and Genesee shale; *O. minuta* (Hall) Beecher, Marcellus shale; *Martinia maia* (Billings) Schuchert is reported in the Onondaga limestone of Ontario; *Lingula manni* Hall, in the Delaware limestone of Ohio; and *Tentaculites scalariformis* Hall, in the Onondaga limestone of New York. Of these species *Liorhynchus limitare* is abundant, occurring more frequently than any other; *Orbiculoidea lodiensis* and *O. minuta* are common, and the remaining ones rare. It is to be noted that the abundant species

[1] *Proceedings of the American Association for the Advancement of Science*, Vol. XXVIII, p. 297.

of this zone occur in the Marcellus shale and later Devonian formations of New York, instead of the Onondaga limestone, and therefore supports Whitfield's conclusion that it is the "equivalent of the Marcellus shale of New York."[1]

DEEP RUN SECTION

In the southern part of Delaware County a number of small streams entering the Olentangy River afford good sections of a part or all of the Delaware limestone. One of the best of these is the small stream known as Deep Run, on the Matthews farm on the eastern side of the river, which enters the river at the ford opposite the Armstrong farm. The stream is rather more than three-fourths of a mile north of the Powell road and bridge, about one-half mile south of the Orange road and bridge, and may be readily reached from Stop No. 42 on the Columbus, Delaware & Marion Electric Railway.

No.		Thickness (Feet)	Total Thickness (Feet)
10.	*Ohio shale.*—Mainly black, thin, somewhat gritty shale, but there are thin layers of greenish or mottled shale. The barometer indicates that 95 feet is shown, in the lower 40 feet of which are numerous concretions, some of which are of large size.	95	175½+
9.	*Olentangy shale.*—Mainly greenish shale, the top of which is sharply shown in a small fall in the stream, and a little below in a steep bank of shale on its northern side, where 10⅓ feet of Olentangy shale is shown. Calcareous concretions occur in the upper part of this shale, which are well shown in the bank just mentioned, where one layer occurs about 3½ feet below its top, another 7½ feet below, and a third 9 feet below, of impure calcareous material which nearly forms a layer. These concretions contain plenty of marcasite or iron pyrites. There is also a brownish layer of shale a foot or so above the lower line of concretions. The measurement is by hand level from the top of the limestone over the covered valley and up the bank to the northeast to the base of the Ohio shale, as shown in a small lateral ravine; but there is a heavy dip in the same direction, so that the measurement of 25 feet is less than the true thickness, probably to the extent of 5 feet.	25+	80½+

[1] *Ibid*, p. 298.

No.		Thickness (Feet)	Total Thickness (Feet)
8.	*Delaware limestone.*—Upper portion thinner-bedded than the lower part of this zone, impure dark colored limestone containing considerable chert. Lower part is fairly massive, impure bluish-gray limestone weathering to a brownish color and containing nodules of chert. This zone is shown on the southern bank of the stream at the upper end of the gorge, where the measurement was made. This zone is not especially fossiliferous, and at the base is a shaly parting.	9½	55½
7.	Layers of brownish limestone, alternating with thick layers of chert, all of which are undulating, giving a contorted appearance to the entire zone.	4½	46
6.	Brownish, fairly thick-bedded limestone, with chert partings, in which is a small abandoned quarry on the northern bank of the run. Thickness, about 6 feet 5 inches.	6½–	41½–
5.	Heavy layer of quarry stone at base of quarry.	1½	35
4.	Shaly to thin-bedded brownish limestone, with layers of chert.	8⅚	33½
3.	Brownish, massive bituminous limestone, which is fossiliferous. Base of the Delaware limestone, but there is no shale zone as in the sections farther south. This gives a thickness of nearly 35½ feet for the Delaware limestone in this glen, which is about 5 feet more than in the Franklin County sections.	4⅔	24⅔
2.	*Columbus limestone.*—Light gray, massive, fossiliferous limestone. The bone-bed is fairly well defined here at the top of this formation, but the change of color from the brownish Delaware to the light gray Columbus is conspicuous. The smooth layer was noted by Mr. G. F. Lamb at a distance of 10 feet below the top of the Columbus.	18½	20
1.	Covered interval to level of Olentangy River.	1½	1½

Mr. G. F. Lamb recently measured this section and made it twenty-one and one-half feet from the river level to the top of the Columbus limestone. The rocks forming the Delaware limestone in this section are quite sharply folded, so that some care is required in obtaining an accurate measurement of their thickness, while at the lower end of the Delaware part of the gorge is a faulted block on the southern side. Zone No. 4 of the above section, showing the alternation of shaly to thin-bedded limestone with layers of chert,

is well exposed about one and one-half miles farther up the river and about one-half mile south of the Lewis Center road, in a run on the farm of Mrs. Amelia Case, a view of which is given in Fig. 2.

Professor Winchell in the Delaware County report described an exposure in the southern part of the county, under the heading of a "Section through the Olentangy Shale and Hamilton Limestone, Five and a Half Miles below Stratford."[1] Professor Winchell

FIG. 2.—View of the zone of alternating limestone and chert in the lower Delaware on the farm of Mrs. Amelia Case.

described a small quarry not far below the ravine of his section, and such an abandoned quarry and river bluff occur a few rods south of Deep Run; so it is believed that the localities are identical. Professor Winchell gave the thickness of the Olentangy shale as thirty feet, which is probably not greater than its true thickness in this glen, and the combined thickness of what he called the Tully limestone (?) and Hamilton (?) (our Delaware limestone) as thirty-seven feet, with seventeen feet of Corniferous (Columbus) limestone below.

[1] *Report of the Geological Survey of Ohio*, Vol. II, Part I (1874), p. 293.

The Tully limestone is a formation succeeding the Hamilton beds of central New York, but as a limestone it does not extend west of Canandaigua Lake. Zone 8 of my section represents Nos. 3 and 4 of Professor Winchell's section, which he called the "Tully limestone (?)." The beds are impure limestone, differing to some extent from the middle and lower Delaware, but not particularly resembling the Tully limestone; and to the writer there does not appear to be sufficient proof, from either the lithological or paleontological standpoint, to warrant the correlation of this zone with the Tully limestone of New York.

THE SANDUSKY LIMESTONE

In 1873 Dr. Newberry briefly described the upper division of the Devonian limestones of Ohio, which he called the "Corniferous," and named it the "Sandusky limestone." His description was as follows:

> In the northern and middle portions of the state the Corniferous limestone shows two well-marked and several less conspicuous subdivisions. Of these the uppermost is a blue, thin-bedded limestone, from fifteen to twenty feet in thickness, and is the rock quarried at Sandusky and Delaware. This I have designated as the *Sandusky limestone*.[1]

Dr. Newberry did not mention any particular locality at Sandusky as typical for the Sandusky limestone, but conversation with Mr. Charles Schoepfle, who has been in the quarrying business for fifty-two years in that city, and who distinctly remembers Dr. Newberry and accompanied him to some extent in his investigation of the quarries, has acquainted the writer with the exposures that were then available. At that time, in 1869 and the early seventies, the principal quarries in Sandusky were those on Hancock Street, in the vicinity of the present quarry of Charles Schoepfle & Son. The present large quarries south of the Soldiers' Home and Sandusky—Wagner Stone Co. and the Hartman quarry—were opened much later than the Hancock Street quarries. The oldest of the quarries south of Sandusky is the Wagner, which, according to Mr. Alex. M. Wagner, was first opened in a primitive manner about twenty-five years ago, the Soldiers' Home quarry about sixteen, and Hartman's nine years

[1] *Ibid.*, Vol. I, Part I, p. 143.

ago. Mr. Schoepfle, however, stated that the first one opened on the Soldiers' Home grounds was the one on Hancock Street in 1877.

LAKE SHORE AND MICHIGAN SOUTHERN RAILROAD QUARRY

So far as known to the writer, none of the quarries in Sandusky or its immediate vicinity affords an excellent continuous section of the Columbus and its overlying limestone. Such an exposure of their contact, however, is to be found in the Lake Shore & Michigan Southern Railroad quarry, two and three-quarters miles southwest of the Lake Shore station in Sandusky, and two and one-half miles northeast of Castalia, in Margaretta Township; and for this reason it will be first described. According to Mr. Wagner, it was worked as much as twenty-five years ago, and my attention was first called to it by Dr. Charles K. Swartz, of Johns Hopkins University, who stated that the contact of the Columbus and Delaware limestones was to be seen in its western part. The upper part of the following section was obtained near the western end of the southern wall of the quarry, and the lower portion near its angle in direction:

No.		Thickness (Feet)	Total Thickness (Feet)
10.	Brownish-gray limestone, which contains fossils as *Leptæna rhomboidalis* (Wilckens) and *Glyptodesma erectum* Hall.	1+	19¼
9.	Chert zone.	⅙	18¼
8.	Brownish-gray limestone, but not encrinal, in which *Leptæna rhomboidalis* (Wilckens), *Chonetes mucronatus* Hall, *Glyptodesma erectum* Hall, and *Grammysia bisulcata* (Con.) were found.	¾	18 1/12
7.	Chert zone.	¼	17⅓
6.	Crinoidal limestone of brownish-gray color, which separates into several layers. *Leptæna rhomboidalis* (Wilckens) occurs, but the zone does not contain many fossils, with the exception of the Crinoid segments, which form an appreciable part of the rock. Shale parting at the base.	4⅚	17½
5.	Compact massive limestone, with crinoidal band near its center; but in other parts of the quarry the entire zone is more of an encrinal limestone. The thickness varies from 1 foot 9 inches to 1 foot 10 inches.	1¾	12¼

No.		Thickness (Feet)	Total Thickness (Feet)
4.	Layer of brownish, calcareous shale, weathering to an ash color, in which part of a fish tooth was found. Lithologically very similar to the shale at the base of the Delaware limestone in Franklin County.	$\frac{1}{4}$	$10\frac{1}{2}$
3.	In upper part of layer, fragments of teeth and fish bones similar to bone-bed at top of Columbus limestone in central Ohio. Lower it is more crystalline in structure, grayish in color, and contains cup corals and other fossils. This contact is shown in Fig. 3, where the collecting bag rests on top of this zone, and the hammer indicates the superjacent shale of No. 4.	$2\frac{1}{2}$	$10\frac{1}{4}$
2.	At this horizon generally a conspicuous zone of *Eridophyllum verneuilanum* E. & H. from 4 to 6 inches in thickness.	$\frac{1}{2}$	$8\frac{1}{6}$
1.	Exposure at angle of southern wall, which extends about as low as in any part of the quarry. This limestone is rather bluish-gray, weathering to a lighter color, somewhat crystalline and fossiliferous. At the angle all of the rock belongs in the Columbus limestone, but there is quite a heavy dip to the west, so that farther along the wall the Delaware limestone is shown as described in the upper part of this section.	$7\frac{2}{3}$	$7\frac{2}{3}$

The brownish limestone alternating with layers of chert, which form the upper part of this section, closely agrees in lithologic characters with the second zone of the Delaware limestone, which succeeds the brownish shales or limestones in the sections in the northern part of Franklin and southern part of Delaware Counties. In the upper part of No. 3 of the above section are a considerable number of fragments of teeth and bones of fish, forming something of a bone-bed, which is overlain by a three-inch layer of brownish shale. Two feet one inch below the top of the bone-bed is a conspicuous *Eridophyllum* zone, similar to the one occurring in the exposures of the Columbus limestone, near Columbus, from two feet eight inches to three feet below its top. It therefore appears to the writer better to draw the line of division between the Columbus and Delaware limestones in this section at the top of No. 3, and refer the five feet ten inches of rock between it and the base of the lowest chert zone, or No. 7, to the Delaware limestone. This will agree lithologically with the sections in the southern part of Delaware and northern part

of Franklin Counties, where there is from four feet eight inches to six feet of limestone or shale intervening between the base of the owest conspicuous chert layer and the bone-bed at the top of the Columbus limestone. On the other hand, there is evidence favoring the reference of the crinoidal layers to the Columbus limestone which is the view taken by Dr. Swartz. He has written me as follows regarding this point:

> I became convinced that the best ground of separation is the faunal break, and it seemed to me that probably the encrinital rock is more nearly related to the underlying than to the overlying strata, especially as it contains *Elæacrinus verneuili*, a characteristic form in the encrinital rock at Columbus. Yet in my dissertation I noted the fact that the encrinital rock may be above the horizon of the Columbus "bone-bed."[1]

It is to be noted, however, that Dr. Bownocker reported the Blastoid—*Nucleocrinus verneuili* (Troost)—from above the bone-bed in the quarries near Marion.[2]

SCHOEPFLE & SON'S QUARRY

This quarry is located on the eastern side of Hancock Street in Sandusky, and is the only one of the various quarries in that section of the city which is now actively worked. The following section was measured on the southern wall toward its western end:

No.		Thickness (Feet)	Total Thickness (Feet)
9.	Rather crinoidal limestone, which in the upper part is quite light gray in color. It contains *Spirifer duodenarius* Hall, and other fossils and corals are quite frequent near its top.	$2\frac{3}{4}$	$15\frac{3}{4}$
8.	Shale parting.	$\frac{1}{6}$	13
7.	Somewhat brownish-gray layer as weathered, containing crinoid segments, some corals, and small *Spirifers*.	$1\frac{7}{12}$	$12\frac{5}{6}$
6.	Shale parting.	$\frac{5}{12}$	$11\frac{1}{2}\frac{3}{4}$
5.	Bluish-gray limestone, not so even-bedded as lower layers, which also weathers rougher on exposed surfaces and contains a considerable number of cup corals, Crinoid segments, and small *Spirifers*.	$2\frac{7}{12}$	$11\frac{1}{3}$
4.	Shale parting.	$\frac{1}{6}$	$8\frac{3}{4}$
3.	Bluish-gray, compact, fairly even-bedded limestones, the upper part of which is thinner-bedded. Building stone, moderately fossiliferous.	$3\frac{5}{6}$	$8\frac{7}{12}$

[1] Letter of January 14, 1905.

[2] *Bulletin of the Science Laboratories of Denison University*, Vol. XI (1898), p. 27.

No.		Thickness (Feet)	Total Thickness (Feet)
2.	Black carbonaceous layer at top, with hackle tooth structure. *Tentaculites scalariformis* Hall is very abundant in the lower part of this zone, but decreases toward its top.	$\frac{3}{4}$	$4\frac{3}{4}$
1.	Massive bluish-gray limestone for building, about 1 foot of which is shown in this part of the quarry. Farther east there is an anticline shown in this wall of the quarry, and at its base beneath the crest about 4 feet of bluish-gray, compact limestone is shown beneath the Tentaculite zone to water-level. There are some *Tentaculites* in this lower rock, and in lithologic character it is not very different from No. 3 above the Tentaculite zone.	4±	4±

The surface of the layer forming the floor of the quarry on the northern side shows conspicuous ripple marks, which run about N. 30° W. and S. 30° E., with an average distance apart from crest to crest of about two feet. In the main, they measured from twenty-two to twenty-six inches apart, but they are not all uniform in separation, and occasionally two run together. This layer with the ripple marks is apparently about five feet three inches below the Tentaculite one. All of the rock in the walls of this quarry is of bluish-gray color, and weathers smooth until the base of the coral and crinoidal layers is reached. On the southern wall of the quarry these layers are conspicuous and project over the smooth underlying bluish-gray rock.

On the western side of Hancock Street, to the southwest of the Schoepfle quarry, and not far from the Lake Erie & Western Railroad, is a small abandoned quarry which, according to Mr. Schoepfle, was opened in 1874 by John Carr and Philander Craig. Near the top of the old quarry wall is a massive layer of bluish-gray limestone, the upper part of which contains fish bones, while its upper surface is rather rough and iron-stained, similar to the top of the Columbus limestone in central Ohio. Below the bone-bed the limestone contains numerous specimens of Brachiopods and corals, although they are not well preserved. The distance of this excavation from the southwest corner of the Schoepfle quarry is only a few rods, and the dip is apparently in that general direction, so that probably the rock of the Schoepfle quarry underlies the bone-bed of the Carr & Craig

quarry. A heavy storm, however, prevented the writer from determining this point, and perhaps the rather crinoidal limestone at the top of the Schoepfle quarry represents the lower part of the crinoidal limestone overlying the bone-bed. This latter view is the opinion of Dr. Swartz, who gives the total thickness of the strata in the Schoepfle quarry as nineteen feet.[1] In the next pit, a short distance to the southwest and nearer the railroad track, succeeding the layer containing the bone-bed is a massive, very crinoidal limestone, which on fresh fracture is brownish-gray to bluish-gray, but weathers on the exposed surface to a light gray color. There is shown above the bone-bed at least three feet of this crinoidal limestone when a layer of chert appears, and in part of the ledge six inches higher is another chert layer. Mr. Schoepfle also stated that, in working for other parties to the southwest of his quarry and west of Hancock Street, he found a considerable quantity of chert in the rock above the horizon of his quarry. Above the crinoidal zone the rock is thin-bedded to shaly, and *Leptæna rhomboidalis* (Wilckens) is abundant. This crinoidal zone apparently corresponds stratigraphically to the similar one noted in the Lake Shore & Michigan Southern Railroad quarry between Nos. 3 and 7 of that section.

To the south of the Carr & Craig quarry, between the two railroad tracks, is another old and abandoned quarry. The dip, however, is reversed, and the Schoepfle quarry limestone appears in this excavation with the bone-bed apparently at the top of the southern wall.

Still farther south, on Pipe Creek, by the northern side of the cemetery, is bluish-gray limestone, some of which is quite massive, which also belongs in the same division as that of the Schoepfle quarry. There is a heavy dip down-stream to the east at this locality, and the massive limestone is exposed up the creek well toward the western line of the Lake Shore Electric Railroad.

To the south of Sandusky, and about one-fourth mile south of the Soldiers' Home, is the quarry of the Wagner Stone Co. About eleven feet of rock is shown in this quarry, the upper three feet of which splits into thin layers from one and one-half to four inches in thickness, although not very even. The rocks of this portion are brownish-gray in color, and weather to a light gray or buff color.

[1] Letter of February 4, 1905.

The remaining part of the quarry has thicker-bedded layers, up to eighteen inches in thickness, although there are thinner ones used for flagging. The thicker layers which are used for building stone are brownish on fresh fracture, but, according to Mr. Wagner, weather to a bluish tint, and do not contain iron. In the lower part of the quarry is quite a massive layer, in which *Chonetes* sp. is common; but above this layer there are comparatively few fossils. In the upper layers, however, which are somewhat crinoidal, occasional specimens of *Stropheodonta demissa* (Con.) Hall, *Pholidostrophia iowaensis* (Owen) Schuchert, *Liorhynchus laura* Billings (?), and *Paracyclas elliptica* Hall (?) were seen. Much of this upper rock is marked with lines of bedding, and it is apparently quite an impure limestone.

To the west of the Wagner quarry, and just south of the Soldiers' Home, is the Hartman quarry, in which eighteen feet of rather even-bedded brownish rock is shown. This quarry extends stratigraphically about seven feet deeper than that of the Wagner Stone Co., and the rock is used largely for building. Fossils occur with about the same frequency as in the Wagner quarry, and the upper part of the rock is slightly crinoidal, similar to the upper layers in the former quarry. Both quarries show very little chert in any of the layers or partings.

CORRELATION OF LIMESTONE IN AND NEAR SANDUSKY

The Wagner and Hartman quarries just south of the Soldiers' Home and outside of Sandusky are correlated with the Delaware limestone of central Ohio.

The limestone in the Schoepfle and adjacent quarries in the city of Sandusky was named the "Sandusky limestone" in 1873 by Dr. Newberry,[1] who gave the localities at which it is quarried as Sandusky and Delaware. It has already been stated in this paper that at the time of Dr. Newberry's investigations the Schoepfle quarry was opened and studied by him; but the present quarries in the Delaware limestone to the south of the Soldiers' Home had not been opened. In Dr. Newberry's "Review of the Geological Structure of Ohio," published in the last strictly geological report issued under his direction, the name "Sandusky limestone" is retained for the upper division

[1] *Report of the Geological Survey of Ohio,* Vol. I, Part I, p. 143.

of what he called the Corniferous limestone, and the quarries at Sandusky and Delaware are given as localities of its occurrence.[1] It will be remembered that in this same volume Dr. Orton, in his "Report on the Geology of Franklin County," named the upper division the "Delaware limestone," "from its occurrence at Delaware."[2] In a paper describing fossil plants from the Corniferous limestone of Ohio, published by Dr. Newberry in 1889, occurs

FIG. 3.—Contact of Columbus and Delaware limestones in Lake Shore & Michigan Southern Railroad quarry two and one-half miles northeast of Castalia. The collecting-bag is on top of the Columbus, and the hammer indicates the superjacent shale.

the following sentence: "They [the fossil plants] are all from the Delaware limestone, the upper division of the Corniferous." A little farther on he speaks of "the white or Sandusky limestone below," apparently applying this name to the lower division of the Corniferous limestone; while he also stated that "the Delaware limestone is much darker and more earthy than the lower division of the Corniferous, and it is evident that it was deposited in shallower water when

[1] *Ibid.*, Vol. III, Part 1 (1878), p. 11. [2] *Ibid.*, p. 606.

the land was nearer and the land-wash more abundant."[1] The above statements apparently indicate that Dr. Newberry had abandoned his earlier opinion and now correlated the limestone in Sandusky with the lower division of his Corniferous or the Columbus limestone of central Ohio, instead of the upper division or Delaware limestone. There is, however, no definite explanation of this change of opinion in any of Dr. Newberry's works, as far as the writer is aware, and perhaps the above interpretation of this paper does not correctly represent him in this matter.

Dr. Charles K. Swartz, of Johns Hopkins University, in the fall of 1903 correctly determined the stratigraphic position of the limestones in the city of Sandusky, and correlated them with the Columbus limestone of central Ohio. He has thoroughly studied the various exposures of the Devonian limestones in Ohio, collected extensively in them, and carefully identified the fossils. Dr. Swartz has written me as follows regarding this subject:

> I find that nearly 87 per cent. of the species reported from the "blue rock" at Columbus and vicinity (including the section from the "smooth rock" to the "bone-bed") occur in that part of the Sandusky limestone in the Lake Erie region which I have referred to the Columbus formation. This includes the more diagnostic forms especially. I think the correlation thus rests on sufficient faunal evidence. Most of these forms do not pass above what I have termed the Columbus formation, or are quite rare in the upper division.[2]

In September, 1904, the writer studied the exposures in Sandusky, and fully agrees with Dr. Swartz in correlating all of the limestone, except the very highest layers, in the Hancock Street quarries with the Columbus formation. It is not improbable that the bone-bed noted in the old quarry on the western side of Hancock Street represents the well-known one in the Columbus region, which occurs at the top of the Columbus limestone, and at least the dividing line between the Columbus and Delaware limestones occurs not more than from three to six feet higher.

Since it is proved that nearly all of the rock to which Dr. Newberry gave the name "Sandusky limestone" belongs in the *lower* instead of the *upper* division of what he called the "Corniferous limestone,"[3]

[1] *Journal of the Cincinnati Society of Natural History*, Vol. XII, pp. 49, 50.

[2] Letter of January 14, 1905.

[3] *Report of the Geological Survey of Ohio*, Vol. I, Part I (1873), p. 143.

it appears to the writer that the name *Sandusky limestone* ought to be dropped. If it were now applied to the lower formation, it would cause serious confusion, since that was named at the same time the *Columbus limestone*, under which designation it is well known in geological literature. It is to be noted that in Dr. Newberry's classification and definition of these two limestones the name "Sandusky" appeared *first*, but on the same page as that of Columbus.[1] It is thought, however, that the above decision is in accordance with Rule 7 of the United States Geological Survey regarding "Nomenclature and Classification," which states that "in the application of names to members, formations, and larger aggregates of strata, the law of priority shall generally be observed, but a name that has become well established in use shall not be displaced by a term not well known merely on account of priority."[2] "Delaware limestone," published by Dr. Orton in 1878, is the next name applied to the upper division of the Devonian limestones of Ohio, and this is now adopted for this formation. In my paper on "The Nomenclature of the Ohio Geological Formations," published in the *Journal of Geology* in 1903,[3] "Sandusky limestone" was used for the upper formation of the Devonian limestones, because, as there stated, it antedated "Delaware limestone" by five years, and the error in correlation between the limestones of Sandusky and Delaware was not known to the writer. The thickness of the Delaware limestone in the Sandusky region, according to Dr. Swartz, is between forty and fifty feet, which is greater than that in central Ohio.

[1] *Loc. cit.*

[2] *Twenty-fourth Annual Report of the Director of the U. S. Geological Survey* (1903), p. 24.

[3] Vol. XI, p. 519, and see pp. 521 and 537.